Cross-Validation of 3D Gamma Comparison Tools

K.M. Alexander [a], C. Jechel [a], C. Pinter [b], G. Salomons [a,c,d], A. Lasso [b], G. Fichtinger [b], and L.J. Schreiner [a,c,d]

[a] *Department of Physics, Engineering Physics, and Astronomy, Queen's University, Kingston, ON, Canada*
[b] *School of Computing, Queen's University, Kingston, ON, Canada*
[c] *Department of Medical Physics, Cancer Centre of Southeastern Ontario at Kingston General Hospital, Kingston, ON, Canada*
[d] *Department of Oncology, Queen's University, Kingston, ON, Canada*

Introduction

- Dose delivery validation is crucial during the commissioning of new treatment techniques and new treatment units
- Comparison of large datasets associated with calculated dose distributions and 3D dose measurements can be difficult
- The **gamma comparison tool** [1, 2] is commonly used to compare 3D dose datasets, enabling quantitative analysis of agreement between two dose distributions by combining dose-difference and distance-to-agreement criteria
- In this work, two independently developed 3D gamma comparison algorithms (a SlicerRT [3] algorithm and an in-house algorithm) were cross-validated and tested

Gamma Comparison

- A 3D gamma comparison is performed using two dose volumes: a *reference volume*, and an *evaluated volume* (which is analyzed for agreement with the reference volume)
- In the equations below, γ quantifies the agreement at some location, where $\vec{r}_r$ and $\vec{r}_e$ are vectors positions of the reference and evaluated points, D_r and D_e are the reference and evaluated doses, and Δd and ΔD are the distance-to-agreement and dose-difference criteria

$$\Gamma(\vec{r}_r, \vec{r}_e) = \sqrt{\frac{|\vec{r}_e - \vec{r}_r|^2}{\Delta d^2} + \frac{|D_e(\vec{r}_e) - D_r(\vec{r}_r)|^2}{\Delta D^2}}$$

$$\gamma(\vec{r}_r) = \min\left\{\vec{\Gamma}(\vec{r}_r, \vec{r}_e)\right\} \forall\, \vec{r}_e$$

- Points in dose distributions are said to agree when $\gamma \leq 1$
- The gamma pass rate is defined as the fraction of voxels in some volume of interest where $\gamma \leq 1$
- 3% and 3mm dose-difference and distance-to-agreement criteria are used throughout this work

References

[1] Low DA. (2010). Gamma Dose Distribution Evaluation Tool. *Journal of Physics: Conference Series* **250** 012071
[2] Schreiner LJ, Holmes O, and Salomons G. (2013). Analysis and evaluation of planned and delivered dose distributions: practical concerns with gamma and chi evaluations. *Journal of Physics: Conference Series* **444** 012016
[3] Pinter C, Lasso A, Wang A, Jaffray D, and Fichtinger G. (2012). SlicerRT – Radiation therapy research toolkit for 3D Slicer. *Med. Phys.* 39(10)
[4] Wendling M, Zijp LJ, McDermott LN, Smit EJ, Sonke JJ, Mijnheer BJ, and van Herk M. (2007). A fast algorithm for gamma evaluation in 3D. *Med. Phys.* 34(5)

Algorithm Testing

- SlicerRT gamma dose comparison tool results were compared to results from an in-house gamma algorithm implemented in Matlab (via MatlabBridge in 3D Slicer)
- Both point-to-point and interpolation-based gamma algorithms [4] were tested
- Two 3D datasets were used for cross-validation of the algorithms:

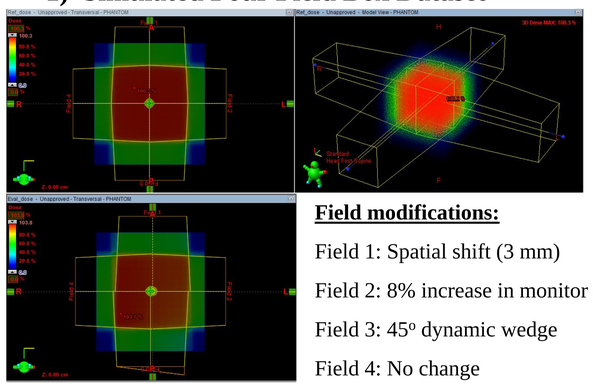
1) Reference volume: Four field box, simulated using Eclipse (1 mm resolution)
Evaluated volume: Modified four field box (1 mm res.)

2) Reference volume: VMAT plan calculated using Eclipse (2 mm res.)
Evaluated volume: Dose calculated from optical CT gel dosimeter measurement (0.5 mm res.)

1) Simulated Four Field Box Dataset

Reference volume

Evaluated volume



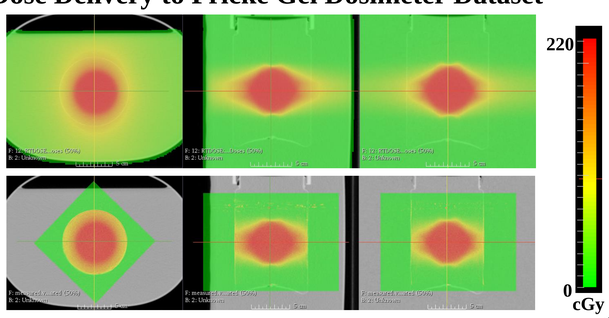
Field modifications:

Field 1: Spatial shift (3 mm)
Field 2: 8% increase in monitor units
Field 3: 45° dynamic wedge
Field 4: No change

2) Dose Delivery to Fricke Gel Dosimeter Dataset

Reference volume (Planned dose delivery)

Evaluated volume (Measured gel dose)



Acknowledgements

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Results

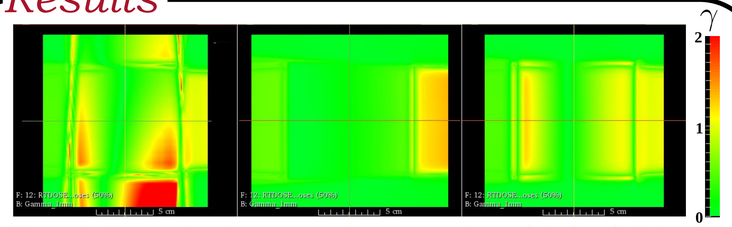

Figure 1. Gamma distribution about the isocenter planes of the four field box dataset (1 mm resolution)

- Perfect agreement was found between the gamma results obtained using the point-to-point SlicerRT dose comparison tool and our in-house point-to-point gamma algorithm implemented in Matlab
- 85% of gamma voxels were found to vary by less than ± 0.1 (Fig. 2) when results from interpolation-based SlicerRT and interpolation-based Matlab gamma algorithms were compared

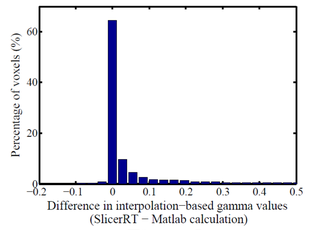

Figure 2.

- This result was anticipated, as choice of interpolation parameters (i.e. sample step size) influences gamma results

Resolution	Four Field Box Pass Rate	Gel Dosimeter Pass Rate
0.5 mm	89.9 %	97.1 %
1 mm	88.4 %	96.0 %
2 mm	86.4 %	90.0 %
3 mm	81.2 %	47.4 %

Table 1. Point-to-point algorithm pass rates for two test cases for a range of resolutions. At finer resolutions, the evaluated distribution approaches a continuous distribution, giving a gamma distribution approaching the theoretical minimum.

	Gel Dosimeter Pass Rate
Reference: Calculated dose **Evaluated: Measured gel dose**	96.0 %
Reference: Measured gel dose **Evaluated: Calculated dose**	91.1 %

Table 2. Point-to-point algorithm pass rates for the gel dosimeter case, with the roles of reference and evaluated distributions exchanged. Noisy gel dosimeter measurements yield a more forgiving comparison in the role of evaluated distribution by providing a range of dose values in close spatial proximity to each reference point.

Conclusions & Future Work

- Results from the gamma dose comparison tool in SlicerRT align perfectly with our in-house point-to-point gamma algorithm, allowing us to recommend the SlicerRT gamma tool as a robust, convenient, and open-source alternative to custom software
- We plan to develop a standard test dataset to perform similar validation of 3D gamma algorithms at other clinics